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C.B. Eaton

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PROGRESS REPORT

BIOLOGICAL AND ECOLOGICAL STUDIES OF THE RED-HEADED PINE SAWFLY AND ITS CONTROL BY AERIAL APPLICATION OF INSECTICIDES

1947 - 1948

By

DANIEL M. BENJAMIN

FOREST INSECT LABORATORY
MILWAUKEE 3, WISCONSIN
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PROGRESS REPORT

1947 - 1948

BIOLOGICAL AND ECOLOGICAL STUDIES OF THE RED-HEADED PINE SAWFLY AND ITS CONTROL BY AERIAL APPLICATION OF INSECTICIDES

* * * * *

SUMMARY

Biological and ecological studies of the red-headed pine sawfly and its control by aerial application of insecticides were restricted to the Shawnee National Forest in southern Illinois during the 1947 field season and the first two months of the 1948 field season. These studies were continued on the Lower Michigan National Forest at Cadillac, Michigan, during the last two months of the 1948 field season. The major portion of the field work was devoted to sawfly surveys and to experimental and routine control aspects of the red-headed pine sawfly problem; biological and ecological investigations were fitted into the control schedules whenever convenient.

Surveys conducted on the Shawnee National Forest during 1947 were exceedingly time consuming because the small irregularly shaped 20-to 350-acre shortleaf pine plantations, making up an aggregate of 25,000 acres, were scattered over an area approximately 40 miles long by 40 miles wide. The heavily infested plantations were assembled in a spray priority listing based primarily on infestation levels and aesthetic and recreational values. Economic levels of 10 percent infestation in plantations averaging 6 feet and less and 20 percent infestation in plantations 7 feet and over were arbitrarily selected as a minimum requiring spraying.

During 1947 an experimental aerial spray program was undertaken on 740 acres of infested shortleaf pine plantations on the Shawnee National Forest in cooperation with the Beltsville Forest Insect Laboratory to determine the most effective dosage for sawfly control. Although weather and foliage conditions were unfavorable and results erratic the one pound DDT-oil solution applied at the rate of one gallon per acre appeared to give the best kills. Commercial applications carried out on approximately 5,000 acres of infested pine plantation during first and second brood sawfly activity, using the one pound DDT concentration, produced variable results. A second experimental control program against third brood sawfly larvae was undertaken in cooperation with the Beltsville Forest Insect Laboratory in 1947 to determine the influence of different degrees of atomization and altitude of flight on sawfly mortality. Results reflected no differences in the variables tested on the 210 acres of sawfly infested shortleaf pine treated since kills approaching 100 percent were experienced on all plots.

Red-headed pine sawfly population surveys were conducted on the Lower Michigan National Forest in 1948 and 2,240 acres of infested red and jack pine plantations were sprayed during the commercial control program. Good kills were experienced on areas of light to no overstory. Under heavy oak cover erratic sawfly kills were experienced.

Biological and ecological investigations conducted on the Shawnee and Lower Michigan National Forests were primarily concerned with survey procedures and the aerial spray program. Studies of egg sites selected by ovipositing female sawflies indicated that under epidemic conditions the majority of eggs found on open growing pines were laid in needles in dense needle clusters, particularly on branches close to the ground on the south and east sides of the trees. No particular selection pattern was apparent on shaded pines. Under endemic conditions the eggs were laid primarily in pines growing in the shade of boundary hardwoods and under persimmon and sassafras clumps. If open growing trees were selected eggs were laid mainly in the dense needle clusters on branches lying on the ground or in dense grass.

Surveys conducted in endemic areas of exceedingly low sawfly density indicated that the shaded portions of the shortleaf pine plantations were maintaining low populations of red-headed pine sawflies. These low population sites appeared as population reservoirs which will probably serve as loci of future sawfly outbreaks.

Larval feeding and colony movement studies undertaken to determine when the sawfly larvae would be most exposed to aerial spray indicated that control measures should be delayed in the shortleaf pine plantations until the third instar had been reached. Mating and oviposition studies revealed a short peak period of adult sawfly emergence and a brief interval between adult emergence and oviposition. Recommendations for control measures directed toward the adult sawflies would, therefore, appear impractical.

Sawfly egg and larval collections revealed the egg parasite, Closterocerus cinctipennis Ashm., as the most important parasite attacking the red-headed pine sawfly in southern Illinois. Many plantations were deleted from the spray schedules during 1947 because of high egg parasitism. Closterocerus was collected on the Lower Michigan National Forest but was rare and of little significance.

Data accumulated concerning the intensity of single 1946 defoliations in unsprayed shortleaf pine plantations on the Shawnee National Forest indicated a linear relationship between the percentage infestation and the percentage defoliation of attacked trees in the 1.0- to 3.9-foot height class and in the 4.0- to 6.9-foot height class. For example, at the 10 percent infestation level in the 4.0- to 6.9-foot height class, an average 28 percent defoliation was experienced. At the 50 percent infestation level a 48 percent defoliation was encountered and at the 75 percent infestation level 58 percent defoliation was incurred. Practical application of these infestation-defoliation data will be made in predicting defoliation damage in shortleaf pine plantations of various sawfly population levels in the recommendations for control applications. In consideration of shortleaf pine's remarkable ability to recover from several complete defoliations, the former 10 percent economic spray levels for trees under 6 feet in height may have to be revised.

During the investigations of survey criteria available for sawfly population analysis studies a sawfly trap baited with two virgin females was designed to attract male sawflies. Catches of 60 males per hour were common in low infestation areas on the Shawnee National Forest. Adult activity, dispersion, and distribution studies are contemplated for the 1949 field season using these traps.

Ecological studies on the Lower Michigan National Forest during 1948 included an examination of areas within jack and red pine plantations that appeared ecologically favorable to the red-headed pine sawfly. Maps showing the relationship between sawfly defoliation and plantation edges, hardwood borders, central hardwoods, and sandblows indicate that light played a significant role in the ecology of the red-headed pine sawfly. Pines growing in heavily shaded areas along hardwood borders and under central hardwoods, as well as pines growing in sandblows, were seemingly preferred by ovipositing females and heaviest defoliations were experienced in these sites. The role of survival in these sites is being investigated.

INTRODUCTION

This progress report is a summary of the control operations and biological and ecological investigations carried out during 1947 and 1948 on the red-headed pine sawfly, Neodiprion lecontei (Fitch), at the Milwaukee, Wisconsin station.

The major portion of the field work conducted during the past two years was devoted to the experimental and routine control aspects of the red-headed pine sawfly problem. Ecological and biological investigations were, through necessity, more or less relegated to the background and fitted into the control schedule whenever convenient. Field studies, both control and ecological, were confined to the Shawnee National Forest during 1947. The first two months of the 1948 field season were spent on the Shawnee National Forest. The last two months of the 1948 field season were spent on the Lower Michigan National Forest.

This report is divided into two sections; the first treating the survey and control aspects of the red-headed pine sawfly problem and the second section, the ecological and biological investigations.

SURVEY AND CONTROL ASPECTS OF THE RED-HEADED PINE SAWFLY PROBLEM

SHAWNEE NATIONAL FOREST

Location

Before discussing the aerial spray programs conducted for control of the red-headed pine sawfly on the Shawnee National Forest, it is of interest to review briefly the events leading up to the recent sawfly outbreak on this forest. The Shawnee National Forest is located in southern Illinois, approximately 300 miles south of Chicago, Illinois, and approximately 75 miles southeast of St. Louis, Missouri (Refer to Map 1). The forest is divided into two purchase units; the Shawnee Purchase Unit, bounded on the east by the Ohio River, extends south from Harrisburg and Shawneetown, Illinois to Metropolis, Illinois; the Illini Purchase Unit, bounded on the west by the Mississippi River, extends south from about Chester and Murphysboro, Illinois to approximately 10 miles north of Cairo, Illinois. The major portion of the control and ecological work over the past two seasons was carried out on the Shawnee Purchase Unit as only one report of the presence of the red-headed pine sawfly (in 1948) was received from the Illini Purchase Unit.

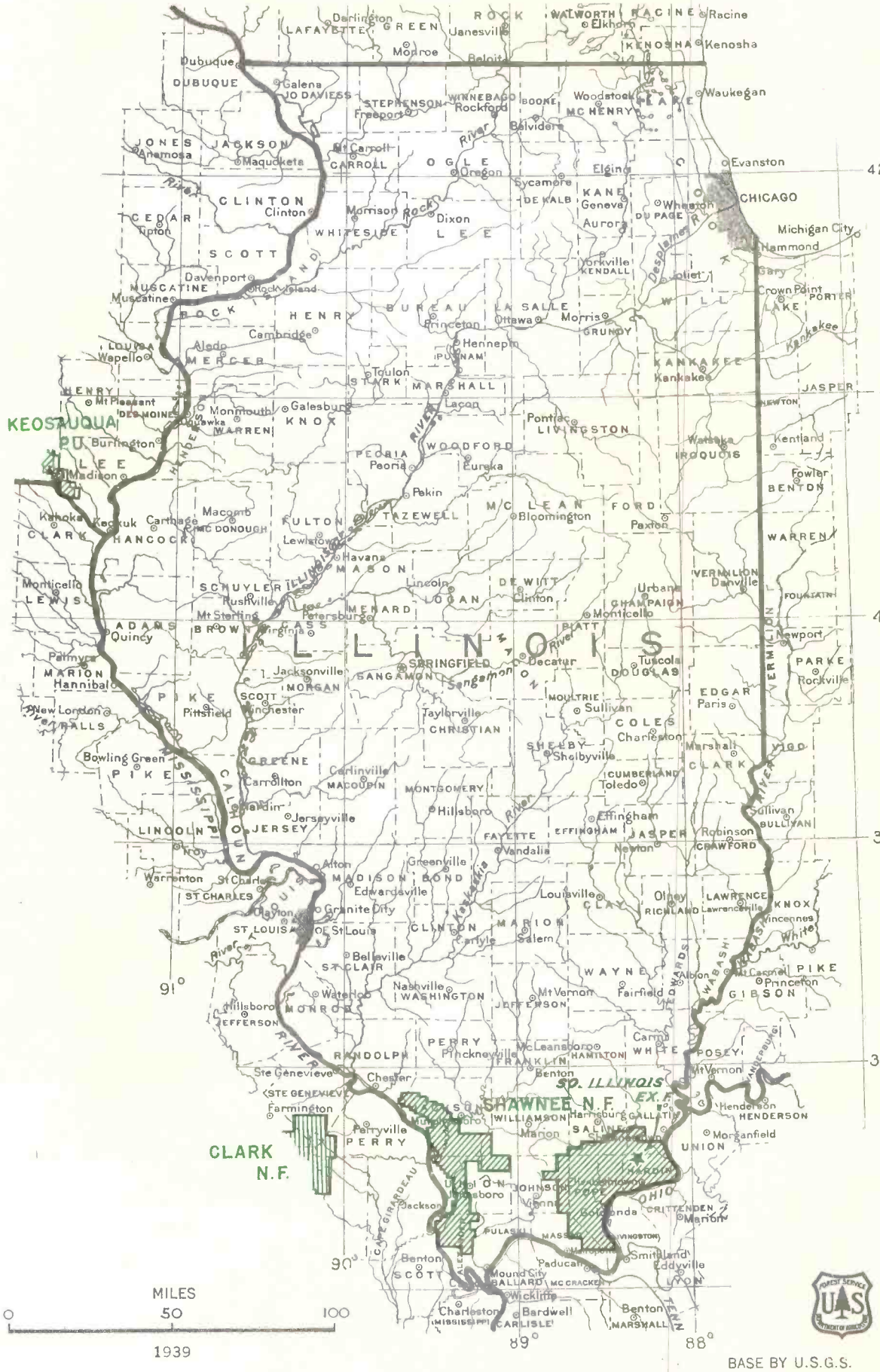
History

Purchase of lands for incorporation into the Shawnee National Forest began in 1933 when the forest was formally established. Planting of pine began in 1935, was continued annually through 1942, and has been resumed since the recent war. Approximately 25,000 acres of shortleaf pine (the major species), pitch, loblolly, and Virginia pines have been planted. Several plantations of shortleaf and loblolly pines, administered by the Soil Conservation Service, have also been incorporated into the forest area. It should be pointed out that the Shawnee Purchase Unit is not in the native pine belt, but is in the oak-hickory region lying south of the northern pine belt and north of the southern pine belt. Only a narrow band adjoining the Mississippi River along the southwestern boundary of the Illini Purchase Unit is within the shortleaf pine belt. The scattered shortleaf pines growing in this belt are overmature, stunted, and of relatively poor quality. These pines appear free of sawflies.

Red-headed Pine Sawfly Outbreak

The conditions encountered when a plant species has been artificially extended beyond its native range and planted in pure dense stands have always been considered conducive to the rapid building-up of insects or diseases to outbreak proportions. It was not surprising, therefore, that shortly after one of the native pine feeding sawflies was reported on the Shawnee National Forest it soon increased to epidemic proportions in the shortleaf pine plantations.

The first report of the presence of the red-headed pine sawfly on the Shawnee National Forest was received from the Shawnee Purchase Unit in October 1945. Larvae collected from a shortleaf pine plantation on the southern half of the forest area were sent to the Milwaukee Forest Insect Laboratory for identification. Prior to 1945 the red-headed pine sawfly had not been reported from Illinois, although it had been collected in surrounding states 25 years earlier.


ILLINOIS
KEOSAUQUA P.U.
CLARK N.F.
SHAWNEE N.F.
SO. ILLINOIS EXP. F.
MILES
0
50
100
1939
BASE BY U.S.G.S.
91°
90°
89°
88°
42°
41°
40°
39°
38°

When the initial outbreak was observed it was confined to an 80-acre shortleaf plantation in which approximately 15 percent of the trees were infested. No control operations were carried out during 1945. Little defoliation was observed during the spring and summer of 1946. In October of 1946, however, considerable alarm was expressed by Forest Service personnel concerning the widespread defoliation throughout the entire Shawnee Purchase Unit. In addition to the initially infested plantation (which, by the fall of 1946, was close to 100 percent infested and almost completely defoliated) approximately 14,000 acres of shortleaf pine scattered throughout the Unit were found to be infested. On many plantations 100 percent infestations with complete defoliation were encountered.

Early in November 1946 control operations were initiated on 113 acres of shortleaf pine in areas of highest recreational and aesthetic value. A 1 percent suspension of wettable DDT powder in water was applied with hand-type atomizers from the ground. Control on the areas treated was considered satisfactory.

Survey Methods

In early 1947 the Forest Service conducted a cursory survey of the sawfly infested plantations on the Shawnee Purchase Unit and prepared an "estimated damage" map of the infestation for use in the 1947 control operations. The writer was assigned to the project in May 1947. The immediate mission was to organize and conduct the prespray survey and give technical assistance during the aerial application of insecticide for control of the sawfly.

Because the small (20- to 350-acre) plantations were widely scattered over an area approximately 40 miles long by 40 miles wide, the feasibility of examining each plantation for sawfly activity was questionable. In order to cover the majority of the plantations in as short a time as possible, single plantations considered representative of plantation groups or blocks, were selected in conducting the egg-larval survey. On each 40-acre plantation 4 plots of 22 trees per plot (1/50-acre per plot) were examined for the presence of sawfly eggs and larvae. The plots were located mechanically at random; taking one plot in each quarter of every 40-acre area examined. As an arbitrary standard, a 10 percent infested plantation (i.e. 10 percent of the trees infested with eggs or larvae) was considered as requiring spraying if the average height of the pines was 6 feet or less. In plantations where the average height was over 7 feet an arbitrary 20 percent infestation base was employed. Plantations in the immediate vicinity of those included in the survey were listed in the tentative spray program as having the same degree of infestation as the plantations actually examined.

All infested and "blocked in" plantations were reexamined prior to spraying, because heavy egg parasitism had reduced the sawfly population in many plantations below the economic level. In this resurvey the sawfly population on 4 plots of 10 trees per plot per 40 acres was determined. The degree of larval development, feeding location, amount of defoliation, together with any information considered pertinent to the spraying operation was recorded. The same economic levels, 10 percent infestation for plantations averaging 6 feet and under, and 20 percent

infestations for plantations averaging over 7 feet were employed in selecting plantations for control spraying. The most heavily infested plantations, i. e. those most likely to suffer immediate serious defoliation, and plantations of highest recreational and aesthetic value were given priority in the spray program listings. Other plantations were listed according to convenience of application.

Experimental Control Operations (First Brood)

Two approaches were followed in the control program against the first brood red-headed pine sawfly larvae in 1947. The first control operation carried out on 740 acres of shortleaf pine, was an experimental program in cooperation with the Beltsville, Maryland Forest Insect Laboratory. The second operation was a routine commercial control program conducted in cooperation with the Forest Service on 3,671 acres of shortleaf and pitch pine. The details and results of the first cooperative program have been summarized in a report prepared by H. A. Bess and C. B. Eaton (1948). Essentially, the concentrations of DDT and rates of application were varied to determine the most efficient dosage for sawfly control. A Stearman airplane from the Beltsville, Maryland Laboratory, equipped with 30, 1/4 B-5 (Spraying Systems Co.) hollow cone spray nozzles, was used during the entire program. The greater part of the control spraying was conducted under adverse conditions of heavy fog, gusty winds, and rains shortly after spraying had been completed. In most instances wet foliage was encountered. Although erratic results were obtained, evaluation of the experimental spraying results indicated that the red-headed pine sawfly could be effectively controlled when oil solutions of 1/2 and 1 pound of DDT per gallon of fuel oil were properly applied at the rate of 1 gallon per acre. Because the 1/2 pound concentration, applied at 1 gallon per acre, appeared too near the lower lethal limits and the results were frequently erratic, the 1 pound concentration was selected for the commercial applications to be applied at the rate of 1 gallon per acre.

Commercial Control Operations (First Brood)

The commercial control program conducted on the Shawnee Purchase Unit in late June and early July of 1947, in cooperation with the Forest Service, was begun with three airplanes furnished by two aerial spray companies. One of the airplanes, equipped with a make-shift spraying assembly, was found unsatisfactory and had to be released. The equipment on the other two airplanes appeared satisfactory and was used throughout the control program.

Spraying was conducted under adverse conditions of heavy fog, gusty winds, wet foliage, and rains immediately following spraying. The 1 pound concentration of DDT in fuel oil was used during the major portion of the control operations. Results were exceedingly erratic and discouraging. Kills ranged from 5 percent to 82 percent with the breaker-bar equipped plane and from 5 percent to 85 percent under the airplane equipped with the 1/4 B-5 nozzles. Over the area as a whole control was not considered satisfactory, and sawfly larvae continued to feed and cause severe defoliation.

Bess, H. A. and Eaton, C. B. 1948.
Progress Report - Airplane Spraying Experiment to Control the Red-headed Pine Sawfly - 1947. Forest Insect Laboratory, Milwaukee, Wisconsin

Commercial Control Operations (Second Brood)

Emergence of a large population of second brood adult sawflies indicated that a second control program would be necessary if severe defoliation was to be avoided. The shortleaf pine plantations on the Shawnee Purchase Unit were resurveyed following the plan outlined; the survey was delayed, however, until the sawfly hatch was well under way. In view of the poor kills experienced under conditions of heavy fog and wet foliage, spraying was delayed until the foliage had dried somewhat or at least until it had stopped dripping moisture.

Control operations on 1,010 acres of heavily infested shortleaf pine plantations were carried out by one commercial N3N airplane equipped with 49 No. 9-F Binks hollow cone spray nozzles. The 1 pound DDT-oil solution was applied at a rate slightly in excess of 1 gallon per acre on all plantations. Kills were again erratic with mortalities averaging less than 50 percent. No valid reason for the poor control was determined. The low pressure at which this spray equipment operated suggested, however, that possibly a large proportion of the insecticide was deposited as exceedingly large droplets and consequently adequate coverage was not obtained.

Experimental Control Operations (Third Brood)

Emergence of a partial third brood of sawfly adults was encountered and steps were taken to initiate an experimental control program to determine what influence different degrees of atomization and altitude of spray release above the trees had on the effectiveness of the spray. The program was undertaken as a cooperative project with the Beltsville Forest Insect Laboratory. Control spraying was limited to 210 acres of sawfly infested shortleaf pine. One commercial N3N airplane equipped with 1/4 B-5 Spraying Systems hollow cone spray nozzles was used throughout the operation. The 1 pound DDT-oil solution was applied at the rate of 1 gallon per acre. The details of this control program are included in the report prepared by Bess and Eaton (1948). Briefly, the number of spray nozzles were varied from 20 to 30 and the altitude of flight from 10 to 50 feet. One plot was sprayed with 30 V-jet flat spray nozzles (1/8" orifice) at 50 feet. An oil red DuPont dye dissolved in the insecticide at the rate of 1 pound of dye per 50 gallons of solution was used to calimetrically evaluate the spray deposit. Evaluation of the filter paper cones hung at 20-foot intervals across the line of flight indicated that coverage was within the limits of variability expected in aerial application of insecticides. Experimentally, the results were most disappointing as kills approaching 100 percent were obtained on all 5 plots. Spraying was carried out under conditions of wet foliage on 3 plots, and within 3 hours after spraying heavy rains covered the area. On the other 2 plots the temperature was below freezing and heavy frost covered the trees at the time of spraying. Aside from the lower temperatures, conditions appeared the same as during the first control program.

Conclusions from Aerial Spraying on Shawnee National Forest

Clear-cut conclusive recommendations for future control operations were difficult to obtain from the experimental and commercial control programs conducted on the Shawnee Purchase Unit during 1947. While early spraying proved exceedingly erratic, the late program gave practical erradication on all plots. Oil solutions of DDT applied at the rate of 1/2 pound per gallon of solution per acre appeared to give excellent results but could not always be relied upon to do so. For this reason the 1 pound concentration applied at the rate of 1 gallon per acre has been recommended for future aerial application for red-headed pine sawfly control. Although no significant differences in sawfly mortality were experienced when the altitude of flight varied from 10 to 50 feet, a 50-foot spraying altitude has been recommended for reasons of safety.

The need for adequate ground to plane or ground to airport radio communications was continually encountered. Prolonged yet unavoidable delays could have been reduced had the field men been able to communicate with the headquarters group.

Spray evaluation, conducted 4 days after spraying, appeared to give most valid results. The procedure followed was to examine 8 to 10 plots of 10 currently defoliated trees per plot per 40 acres across the line of spray flight. On these plots the presence or absence of sawfly larvae was recorded as follows:

No larvae	Scattered larvae	Intact colonies
X	X	X

If the number of larvae present 4 days after spraying appeared to be fewer than could have caused the amount of defoliation, or if the larval colony was reduced in size or broken and scattered, the tree was tallied as "scattered larvae" indicating partial control. If the number of larvae present after spraying appeared sufficient to have caused the current defoliation and the larvae were feeding in an organized colony, the tree was tallied as "Intact colony", i. e. no control. If no larvae were present on the currently defoliated tree, complete erradication was assumed to have been accomplished. In most areas of poor control, a partial kill was obtained even though feeding larvae were still observed on the trees. This partial kill, observed many times throughout the control programs, was corroborated by tagging known numbers of colonies prior to spraying and examining the trees at intervals after spraying. In calculating the percent reduction or control, "No larvae" and "Scattered larvae" were considered as satisfactory kill.

LOWER MICHIGAN NATIONAL FOREST

Commercial Control Operations - 1948

Because a drastic reduction was encountered in the red-headed pine sawfly population on the Shawnee National Forest in 1948, temporary field headquarters were moved from this Forest to the Lower Michigan National Forest. The pine plantations on this National Forest lie within the natural range of jack pine and red pine and have suffered severely from sawfly attack a number of times in the past.

The first red-headed pine sawfly outbreak on the Lower Michigan National Forest was reported in 1930; the high sawfly populations continuing through 1935. Control measures were applied from the ground during 1934 and 1935 on the Cadillac Ranger District. Following 2 years of relatively low sawfly population (1936-37) a second major outbreak period was encountered. During this 3-year outbreak spraying operations were applied from the ground over a large plantation acreage. During 1938, 7,000 acres of heavily infested plantation on the Manistee Ranger District were treated. In 1939, 4,600 acres of red and jack pine were sprayed on the Manistee Ranger District and in 1940, 120 acres were treated. From 1941 through 1944 the sawfly population was at low ebb. In 1945 an increase was again encountered and serious defoliation experienced in 1946. Approximately 1,800 acres of pine were treated during the aerial control operations in 1946 and 3,300 acres in 1947.

During the 1948 control program on the Cadillac and Manistee Ranger Districts of the Lower Michigan National Forest 2,240 acres of red-headed pine sawfly infested jack and red pine plantations were sprayed from the air. The procedures followed in conducting the survey, spraying operations, and post-spray evaluation were essentially the same as were used in 1947 during the sawfly control operations on the Shawnee National Forest. In general, the sawfly survey was delayed until larval hatch was well under way. Populations of the egg parasite were of no significance in reducing the sawfly population. The one pound oil solution of DDT used on all plantations was applied at the rate of 1 gallon per acre. Mortalities ranging from 30 percent to 99 percent were encountered, depending upon the amount of overstory covering the pines. In areas of light or no hardwood overstory, satisfactory sawfly kills were obtained.

BIOLOGICAL AND ECOLOGICAL INVESTIGATIONS

INTRODUCTION

Biological and ecological investigations of the red-headed pine sawfly were relegated, over the past two field seasons, to a minor position due to the pressure of survey and control operations. In general, the period between surveys and control activities was devoted to these studies.

Investigations conducted on the Shawnee National Forest during 1947 and the first two months of the 1948 field season were directed primarily toward aspects concerned with survey procedures and the aerial spray program. Information obtained from studies of egg site selection exhibited by the female sawflies and studies of larval colony movements greatly facilitated sawfly population surveys. Studies of susceptible and low population areas yielded information concerning population reservoirs; areas in which the sawflies maintain low populations between outbreaks. Colony movement studies aided in timing spray operations; one of the most vital considerations in control work. An attempt was made to evaluate the sawfly infestations from an economic damage viewpoint to determine the level in the sawfly outbreak where control operations are necessary to avoid severe defoliation.

Biological and ecological investigations were carried out during and following control activities on the Lower Michigan National Forest the last two months of the 1948 field season. Particular emphasis was placed on studies of areas within red and jack pine plantations which appeared ecologically favorable to the red-headed pine sawfly.

SHAWNEE NATIONAL FOREST INVESTIGATIONS

Egg Site Selection

A study of the egg sites selected by ovipositing female sawflies was undertaken during the first brood emergence period and continued through the oviposition period of the third brood in 1947. Under conditions of outbreak and high population levels, sawfly egg batches were observed on both open growing and shaded shortleaf pines. On the open growing trees the females appeared to prefer the lower branches, particularly those branches in close approximation with the ground although they would oviposit in needle clusters on various parts of the pines in some instances. The females appeared to select the lower aspects of the denser needle clusters and eggs were encountered most frequently in needles on the south and east sides of the tree. Few eggs were found on the leader and main stem needles of shortleaf pine. When previously defoliated open growing shortleaf pines were oviposited on, available regrowth was selected. Often when a single branch tip contained needles, or only sprouts were present, these needles were oviposited into. In some instances even needle bracts were selected. In shaded areas the egg site selected did not appear to follow any particular pattern. Eggs were laid in the dense needle clusters and in the leader and exposed needles in about equal frequency.

Under conditions of low population densities few open growing trees were attacked. When eggs were laid in open growing shortleaf pines the site selected was invariably the densest needle clusters lying in close approximation with the ground or in the grass, as illustrated in figure 1. Pines growing along the borders of plantations in the shade of hardwoods and under isolated patches of sassafras and persimmon were most commonly selected for oviposition. No particular egg site selection pattern appeared to be followed by the female sawflies in ovipositing in these shaded pines. Needles in dense clusters, as well as leader needles, were selected. During bright sunny days, however, female sawflies were observed examining many needle sites prior to settling down to oviposit. The females appeared to select sites in darkest shade on the side of the tree opposite the sun. Cursory surveys conducted during 1948 indicated that the sawfly population was far below the economic levels experienced on the shortleaf pine plantations during 1946 and 1947. During these surveys shortleaf pines growing along the hardwood boundaries and pines growing under scattered sassafras and persimmon patches within plantations were frequently found to be infested with small colonies of actively feeding sawfly larvae. Areas of shaded shortleaf pines having very low sawfly populations were encountered on practically every low population plantation examined in early 1948. Figure 2 illustrates one of these low population sites: the light areas within the plantation are sassafras patches under which low sawfly populations were encountered. It appears that here, in these shaded portions of the shortleaf pine plantations, a reservoir of sawflies exists which may serve as a locus of future outbreaks when environmental conditions again become favorable.

Figure 1. Open growing shortleaf pine with densely shaded needle clusters in close approximation to ground heavily infested with sawfly eggs.

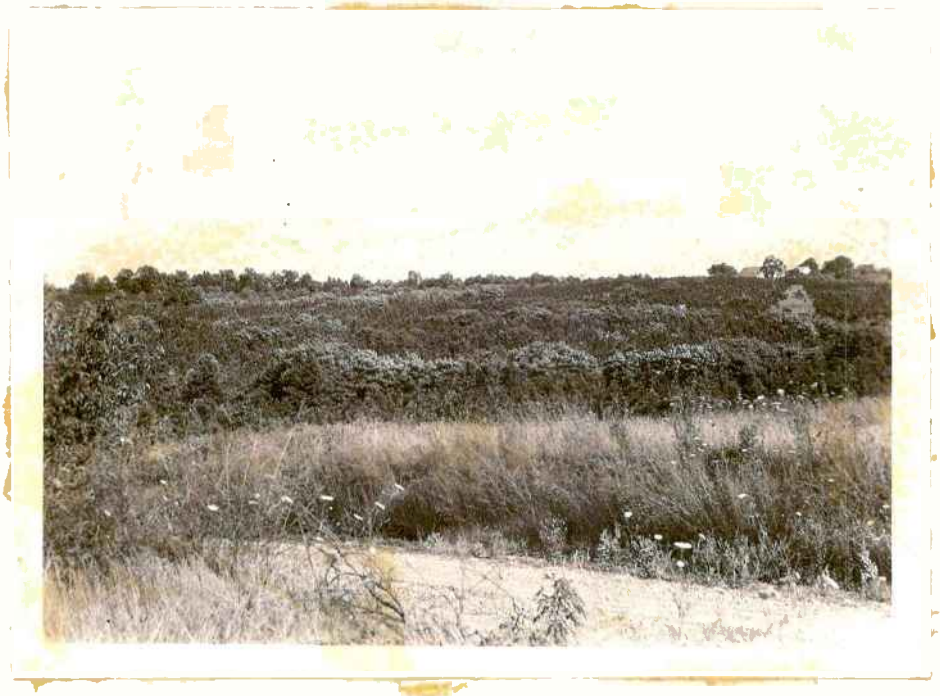


Figure 2. Shortleaf pine plantation with scattered overtopping patches of sassafras shading low sawfly populations: (light areas are hardwood patches).

LARVAL FEEDING AND COLONY MOVEMENTS

A study of the larval and colony movements was undertaken to determine when the larvae would be most exposed to aerial sprays. In this study 43 colonies on 20 open growing shortleaf pines were observed at 2-day intervals throughout the second brood activity. Shortly after emergence the first instar larvae commenced feeding on the needles from which they hatched or on adjacent needles well back in the dense needle clusters. The larvae chewed small ragged holes or notches in the edges of the needles, generally taking but a few pieces from any one spot on the needle. The first instar progeny of each female fed as a gregarious colony, staying for the most part in the vicinity of the oviposition site in a relatively unexposed location. After the larvae molted, the colony either moved a short distance from the egg site and continued to feed on the lower aspect of the branch or moved to a sheltered position directly above their egg site. The second instar larvae began to do noticeable damage when several of them assembled around the end of a single needle to feed. The larvae stripped down the edges of these needles, leaving only the central vascular tissue. These central portions quickly dried and soon appeared as reddish, straw-like masses. These straw-like flags served as a useful criterion in prespray survey operations as they were visible from a considerable distance. After molting a second time the larvae moved out into the open and ascended the tree to feed on the leader and branch tip needles. These third instar larvae and subsequent 4th and 5th instars fed voraciously in well exposed positions. The larvae, often 3 to 5 to the needle, fed as a colony and moved down the leader and branches as they consumed the needles. Frequently the larvae gnawed cup-shaped holes into the tender bark of the current growth. After completely defoliating a branch the larval colonies moved to an undefoliated branch. No apparent pattern was followed in the choice of the next branch. Often a colony would move over several undefoliated branches to select some well exposed distant branch for their feeding site. Feeding continued during the 5th instar, but gradually decreased in intensity. As the individual larvae completed their feeding they spent a short period of inactivity on the tree, then migrated to the ground to spin cocoons. In sandy soils cocoons were spun in the sand and under leaves and twigs. In heavy soils the larvae migrated varying distances from the tree to spin. This migratory habit and consequent widespread distribution of the cocoons renders cocoons of little practical value in red-headed pine sawfly population surveys.

Larval feeding was encountered at air temperatures as low as 52° F. and at temperatures as high as 108° F. Below 55°, however, feeding was markedly reduced and the larvae remained motionless in close compact colonies on the branches. During periods of high temperatures (above 100° F.) the larvae generally moved to more sheltered positions in the shade and continued their feeding. In the 1st instar, however, feeding was interrupted during these periods. Newly hatched larvae remained inactive on their egg site, and frequently suffered heavy mortalities if high temperatures continued. The dried bodies of these 1st instar larvae were often found in situ on the egg site. These dried larvae were never encountered during periods of low temperatures (below 90° F.). Disease did not appear to be the cause of death of these 1st instar larvae. Larval feeding was not interrupted by darkness and feeding was often observed several hours after sunset.

Warm summer rains did not appear to cause prolonged interruption of feeding, and the larvae generally remained in their feeding positions on the needles. Cold fall rains, however, caused the larvae to move in toward the more protected portions of the tree, and frequently entire colonies were found closely grouped against the main stem of the tree.

The results of the larval feeding and colony movement studies suggest that the application of control measures should be delayed until the majority of the larvae have reached the 3rd instar and have moved into the open on shortleaf pines.

MATING AND OVIPOSITION STUDIES

Mating and oviposition activities of adult sawflies were investigated to determine the feasibility of applying control measures during or shortly after the adult emergence period. Emergence records collected in southern Illinois indicated that the peak of emergence extended over approximately a 5- to 7-day period with only a few scattered adult females emerging after the peak had been attained. Mating generally occurred immediately after emergence — the males being attracted to the virgin females and actively seeking them out. Male sawflies were frequently observed to appear within 30 seconds after liberation of virgin females during the peak of adult flight. Copulation lasted from 10 to 50 minutes and the females began oviposition within a few minutes after mating was completed. Both caged and wild female sawflies discharged their egg supply within 24 hours; dissection of wild and caged females following oviposition indicated an average of 3.04 ± 1.66 unlaid eggs of their total 137 ± 40.6 egg capacity. Additional eggs were not matured and the females generally remained in the vicinity of their egg batch for several hours until they were either captured by predatory insects or fell to the ground where ants and other predators picked them up.

Females were observed ovipositing at temperatures as low as 46° F. and at temperatures as high as 108° F. Oviposition was observed several hours after dark when egg laying had been begun prior to sunset.

Because of the short adult emergence period and the brief interval between emergence and completion of oviposition, recommendations for control measures directed toward the adult sawflies would appear impractical.

PARASITES AND PREDATORS

Larval collections were made from several sawfly infested plantations throughout the Shawnee Purchase Unit and placed in rearing for parasite emergence. These parasites will be submitted for identification at a later date. Parasitism varied considerably throughout the forest and ranged from 5 percent to over 90 percent.

The egg parasite, Closterocerus cinctipennis Ashm., appeared to be the most important parasite of the red-headed pine sawfly in southern Illinois. During the first brood emergence in 1947 several plantations were deleted from the spray schedule when egg parasitism was found to have reduced the larval hatch below economic levels. Parasitism by the egg parasite reduced the larval hatch below economic levels in many plantations during the second and third broods in 1947.

Closterocerus also appeared to be an important control factor in reducing sawfly populations in 1948; parasitism was above 90 percent on 12 of 15 plantations examined during the first brood survey. During the cursory sawfly survey conducted on the Shawnee Purchase Unit in September 1948, small numbers of sawfly eggs were collected on 4 of the 25 plantations examined. Infestations in these low population areas were confined to densely shaded, over-topped pines. Egg parasitism of second generation eggs on 2 plantations averaged over 90 percent. Parasitism of 3rd generation sawfly eggs on the other two plantations averaged over 94 percent.

Little predator activity was observed in the Shawnee Purchase Unit sawfly infestations. Erax aestuans Linn., a common Eastern United States robber fly, was observed capturing male sawflies in the vicinity of caged virgin females and the wheel bug, Arilus cristatus (L.), was observed feeding on sawfly larvae. Feeding damage of an unidentified egg predator was encountered in a few shortleaf plantations.

ECONOMIC DAMAGE LEVEL EVALUATION

During the prespray survey of sawfly infested shortleaf pine plantations in 1947 on the Shawnee National Forest, data was accumulated concerning the intensity of single-brood (1946) defoliations in unsprayed shortleaf pine plantations. The primary object was to determine if a relationship existed between the percentage infestation and the percentage defoliation in stands of various heights, and if so where, in the infestation intensity picture, severe defoliation was experienced. It was hoped that this percent infestation criterion could be used as a sound basis for recommending initiation of control operations.

During this survey a record was made of all trees (22 trees per plot) on each of the 4 plots per 40 acres examined. The height of the trees was estimated to the nearest foot. In estimating the percentage defoliation a geometric progression estimate was employed. The defoliation classes used were 0-3-6-12-25-50-75-87-93-96-99-100 percent. The basic procedure followed in estimating the percent defoliation was to assign the tree to first, a broad classification (i.e. was the defoliation above or below 50 percent), and then to assign it to its proper class through mental comparisons with the next lower or higher category. An example may clarify the procedure. Assuming an 87 percent defoliated tree is encountered, it is immediately obvious that defoliation is in excess of 50 percent. The next decision places the defoliation between 75 and 100 percent. The decision remaining is to judge how much greater the defoliation is than 75 percent, i. e. whether it is closer to the 87 percent than to the 75 or the 100 percent classes. This particular tree appears to lie approximately intermediate between the 75 and 100 percent levels and is assigned, therefore, to the 87 percent defoliation class. The same procedure is followed in assigning defoliated trees to classes below the 50 percent level.

Naturally, a small amount of indecision was encountered when this method of approach was first employed in assigning trees to defoliation classes between the 75 and 99 percent levels and between the 25 and 3 percent levels. This geometric approach to defoliation estimation also appeared on first examination to be more complicated than the more frequently used 10 percent class estimates. The writer and several associates have compared defoliation estimates using both systems and, after an initial period of introduction, found the estimates based on the geometric progression more reliable than the 10 percent class estimates.

In the preliminary analysis of the sawfly defoliation data collected on the shortleaf pine plantations, the average height of each plantation was calculated and the stands arranged in 3 height classes (1.0 to 3.9, 4.0 to 6.9, and 7.0 feet and over). The percentage infestation was calculated for each plantation. Statistical analysis of the infestation-defoliation data (Coefficient of Correlation) indicated a linear relationship between the percent infestation and percent defoliation in the 1.0- - 3.9-foot and 4.0- -6.9-foot classes. As the majority of the infested shortleaf stands on the Shawnee National Forest were in the lower height classes, the data collected on the 7.0-foot and over class were not sufficient for statistical treatment. Fisher's Analysis of Variance was also applied to the data and this analysis suggested a very highly significant linear relationship between infestation and defoliation. No significant difference appeared to exist between the straight line fitted through the data and any curved line possibly fitted through the data. For this reason a straight line fitted through the data (using the Coefficient of Correlation Method) was selected to indicate the relationship between infestation and defoliation.

The graph of the 4.0- to 6.9-foot shortleaf pine class defoliation data, presented in figure 3, shows the increase in the percent defoliation of the attacked trees encountered as the number of trees per unit area (percent infestation) increased. For example, at the 10 percent infestation level 28 percent defoliation was encountered. At the 50 percent level 48 percent defoliation was encountered and at the 75 percent level, 58 percent defoliation was experienced.

The graph representing the relationship between infestation and defoliation in the 2.0- to 3.9-foot class indicates slightly heavier defoliation at the various infestation levels (figure 4). This increase is to be expected as these smaller trees have less foliage than trees in the 4.0- to 6.9-foot class.

Practical application of these infestation-defoliation data will be made in predicting defoliation damage in shortleaf pine stands at various sawfly population levels. In the past spraying was begun when 10 percent of the trees were infested with sawfly larvae in pine stands averaging 6 feet and less. In consideration of shortleaf pine's remarkable ability to recover from severe defoliation, this 10 percent level may have to be revised.

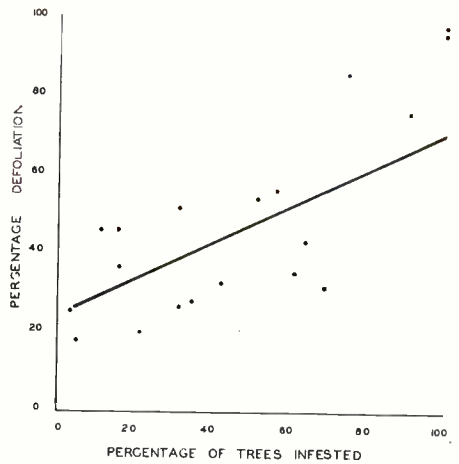


Figure 3. Graph showing relationship between percentage of shortleaf pine trees infested and percentage defoliation of infested trees caused by single 1966 attack of 4.0 - 6.9 height class. r = .818, 5% level = .423, 1% level=.537.

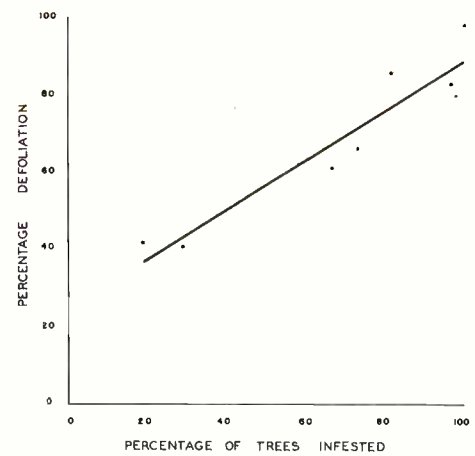


Figure 4. Graph showing relationship between percentage of shortleaf pine trees infested and percentage defoliation of infested trees caused by single 1966 attack of 1.0 - 3.9 height class. r = .939, 5% level = .707, 1% level = .834.

A preliminary investigation was begun in the jack pine plantations of the Lower Michigan National Forest in 1948 to determine the relationship between the number of larval colonies per tree and the percentage infestation. Table 1 indicates that in jack pine plantations the percentage of trees with multiple colonies increased as the percent infestation increased. It is hoped that sufficient data will be accumulated during the 1949 field season for jack and red pines to allow prediction of defoliation damage at various sawfly infestation levels and to give us a more sound basis for recommending initiation of control spray operations in that area.

Table 1. Number of Red-headed Pine Sawfly Colonies per Tree at Various Infestation Levels in Jack Pine Plantations at Manistee, Michigan

Number of Colonies per Tree	Percent Infestation						
	1 - 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69
	Percent of Trees per 25-tree Plot						
0	92.8	84.0	77.8	66.0	59.0		36.0
1	6.4	14.7	17.5	19.0	25.0		16.0
2	0.8	1.3	3.6	9.0	11.0		20.0
3			0.7	4.0	4.0		12.0
4			0.4	1.0	1.0		8.0
5				1.0			-
6							4.0
7							-
8							4.0

DEFOLIATION RECOVERY INVESTIGATIONS (SHORTLEAF PINE - SHAWNEE NATIONAL FOREST)

Forty-four shortleaf pine trees completely defoliated in late 1946 were tagged in 1947 to evaluate the mortality caused by this severe defoliation. A small square of phloem was removed from the base of each tree so subsequent growth could be identified and measured. All of the trees in this group refoliated during the spring of 1947, and the majority of them were putting out terminal growth by mid-1948. Diameter growth measurements will be made at a later date.

Sixty shortleaf pines with varying degrees of first brood defoliation in 1947 were tagged to evaluate the effects of a single first brood defoliation. All of the trees in this group had refoliated by the middle of July 1947, and by the end of the season appeared healthy and vigorous.

Ten trees completely defoliated during the second brood activity were tagged in late August 1947 to evaluate the effects of this mid-season defoliation. All of the trees in this group had refoliated by mid-September 1947. None of the 110 trees in the above groups died during the 1947 or 1948 seasons. Mortality observations will be made again in 1949.

Summarily speaking, little shortleaf pine mortality has been experienced to date due to sawfly defoliation on the Shawnee National Forest. Neither single complete defoliations nor multiple complete defoliations have caused serious kills. In areas of 100 percent defoliation, less than one percent tree mortality has been experienced. Few dead branches have been observed in these heavily defoliated areas. The decrease in annual increment caused by these defoliations has not been determined. Figure 5 illustrates ability of shortleaf pines to recover following complete fall defoliation. Terminal growth put out in May 1947 was mainly confined to the upper part of the tree.

Figure 5. Shortleaf pine completely defoliated in fall of 1946 putting out terminal growth in May 1947.

SAWFLY TRAPPING STUDIES

During the adult sawfly emergence period of the 2nd and 3rd broods in 1947, large numbers of wild male sawflies were observed in the vicinity of caged sawfly cocoons from which female sawflies were emerging. Wild males were frequently observed to appear within 30 seconds after virgin females were liberated from closed vials in heavily and lightly infested shortleaf pine plantations. Since female-baited traps have been successfully used in attracting males of other species of insects this stage of the insect suggested another possibility in survey and population analysis investigations. A trap consisting of an inverted one-pint ice-cream container, inside of which two virgin females were caged in a hardware cloth container, was designed to catch the attracted males. Tree tanglefoot smeared on the inner side of the container caught few of the males attracted, although large numbers of males were observed in the vicinity of the traps. When the tree tanglefoot was smeared on the exterior of the trap practically all of the males attracted were caught. Photos 6 and 7 illustrate the superiority of the external over the internal application of the adherent. Table 2 illustrates the efficiency of these traps in a stand where the sawfly infestation was below the one percent level.

Although data obtained from virgin female-baited insect traps are frequently erratic and inconsistent under conditions of very high and very low population densities, these traps may prove a useful adminicle in adult activity, dispersion, and distribution studies. Some of these aspects will be investigated during the 1949 field season.

Figure 6. Sawfly trap baited with two virgin females, and internally applied tanglefoot.

Figure 7. Sawfly trap baited with two virgin females and externally applied tanglefoot.

Table 2. Accumulative Male Red-headed Pine Sawfly Catch with Female-Baited Trap and Externally Applied Adhesive.

Time	Accumulative Male Catch
10:25 A.M.	Set
10:30 "	3
10:35 "	7
10:40 "	18
10:45 "	28
10:50 "	35
10:55 "	38
11:00 "	44
11:05 "	49
11:10 "	53
11:15 "	56
11:20 "	57
11:25 "	60
12:25 P.M.	80

LOWER MICHIGAN ECOLOGICAL STUDIES

A low adult sawfly emergence combined with heavy egg parasitism reduced the sawfly population below economic levels on the Shawnee Purchase Unit during the first brood of 1948. For this reason field studies were terminated on the Shawnee in mid-July and the writer moved temporary field headquarters to the Lower Michigan National Forest where the red-headed pine sawfly continued in outbreak proportions. Technical assistance was rendered the Forest Service in their sawfly and spittlebug survey, aerial control operations, and postspray evaluation work. Ecological studies were continued throughout the remainder of the field season; especial emphases were placed on an evaluation of ecologically favorable sites, an evaluation of areas of past and present high sawfly populations, and areas of initial sawfly attack.

ECOLOGICALLY FAVORABLE SITES

Shaded Areas

Frequent comments have been made concerning the spread of the red-headed pine sawfly infestation from the edges inward toward the center of pine plantations. This characteristic pattern was observed on the older jack and red pine plantations on the Lower Michigan National Forest and found to be particularly evident where hardwoods bounded the pine plantations which had already closed. Defoliation was generally heavier under these hardwoods than on trees in the open. Maps of these plantation edges, together with crown projections of the hardwood crowns indicated that the heaviest defoliation was invariably encountered under the hardwoods. Edge maps were made of several sawfly infested pine boundaries to further investigate this relationship. Figures 8, 9 and 10 illustrate the relationship between edge-hardwood and heavy sawfly defoliation.

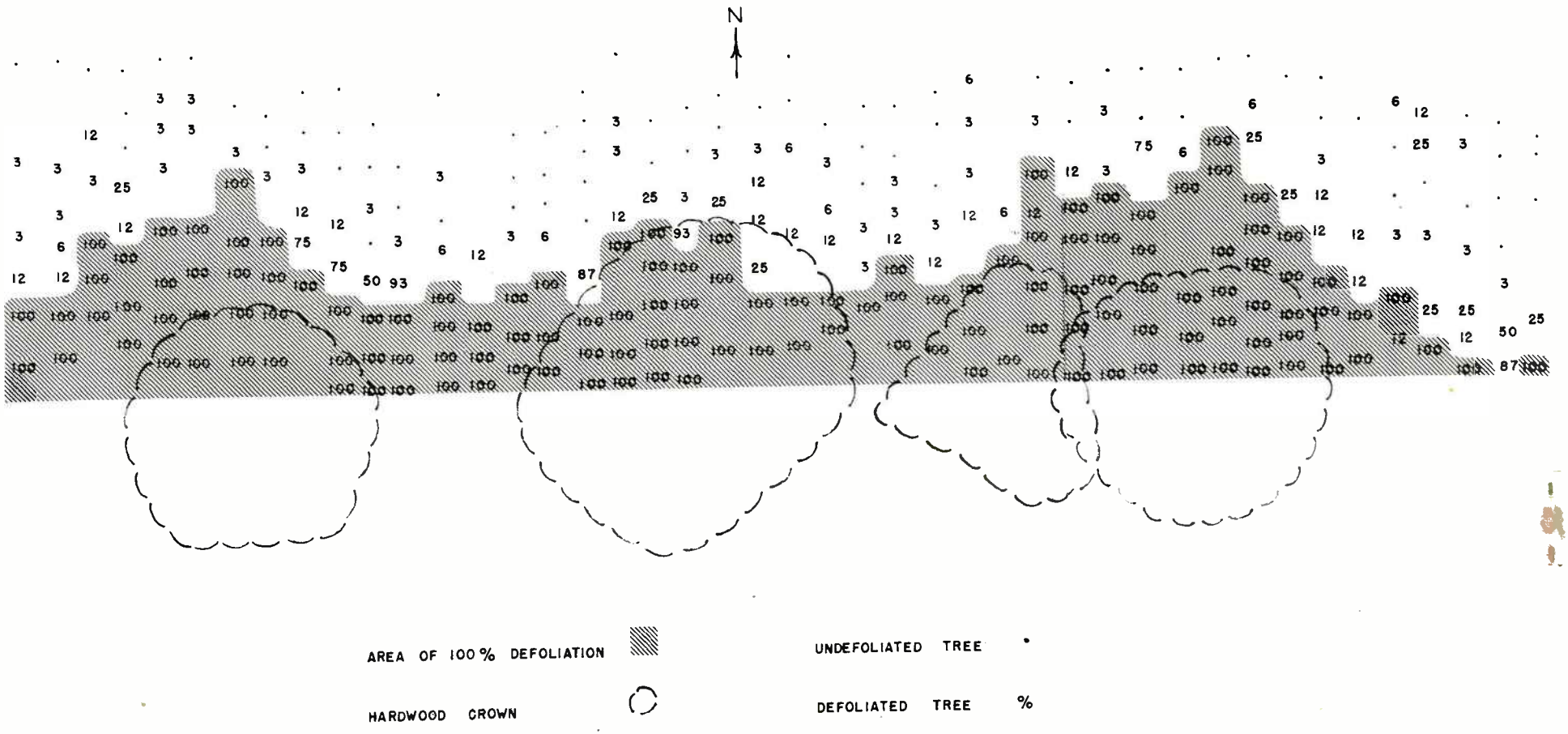


Figure 8. Map of south edge of jack pine plantation showing heavy defoliation under and in vicinity of hardwood crowns.

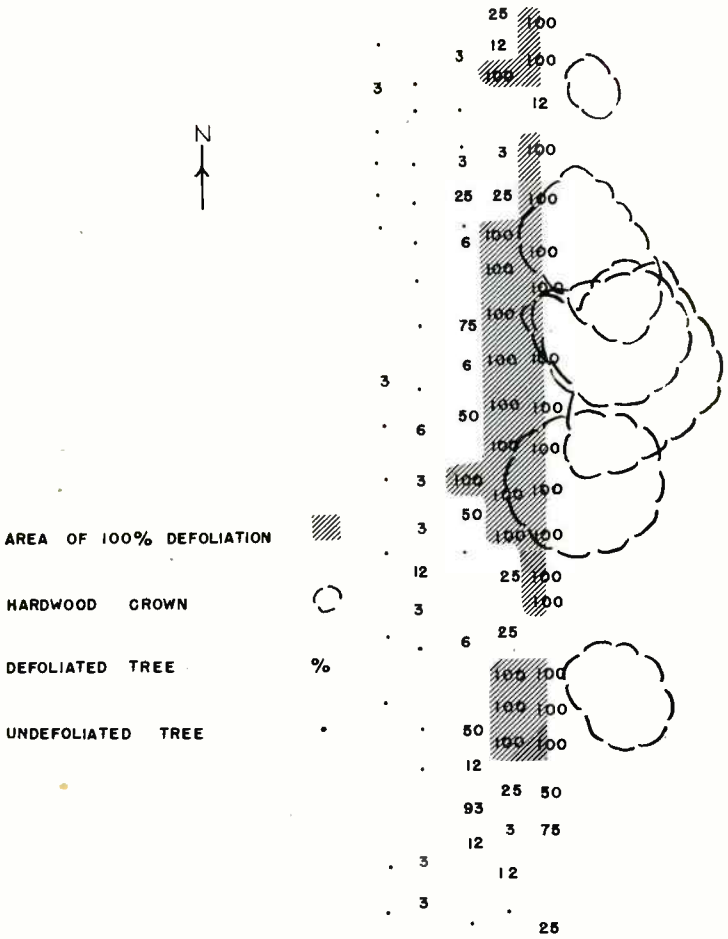


Figure 9. Map of east edge of jack pine plantation showing heavy defoliation under and in vicinity of hardwood crown.

Figure 10. Heavy sawfly defoliation of jack pine adjacent to east hardwood edge.

In investigating this shade-edge relationship further, a number of closed jack pine plantations were observed in which large centrally located hardwoods had been left when the area was planted. The pines planted under these hardwoods had grown well, and were but slightly shorter than the surrounding open growing trees. During the sawfly outbreak of 1946-47 the sawfly population appeared to have been more concentrated under these hardwoods and severe defoliation resulted. In most instances complete defoliation had occurred, while the surrounding trees suffered little damage. Figures 11 and 12 illustrate the severity of the attack under one of these hardwoods. Figures 13 and 14 show the mortality encountered under a central hardwood. The possible relationship between light and sawfly infestation will be further investigated during the 1949 field season. At present it appears that light plays a significant role in the ecology of the red-headed pine sawfly and may be one of the controlling factors in the choice of trees by female sawflies.

Figure 13. Isolated hardwood left at planting time in jack pine plantation.

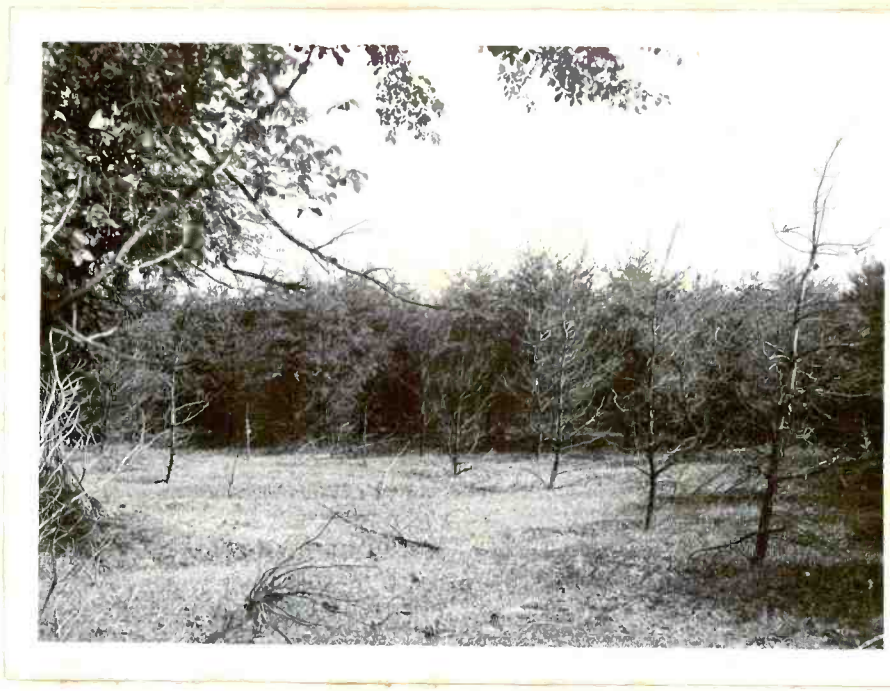


Figure 12. Mortality of jack pine under overtopping hardwood within jack pine plantation.

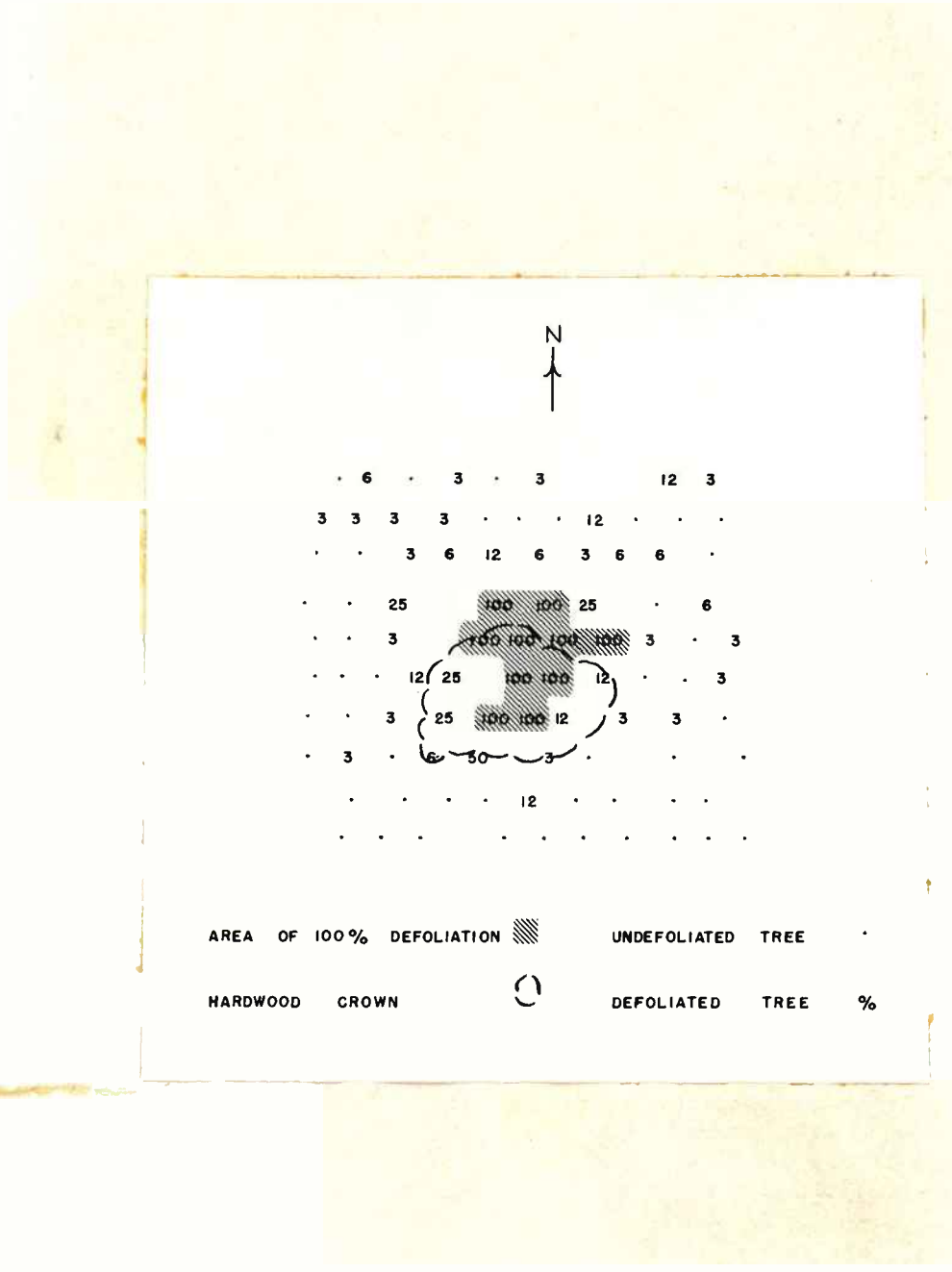


Figure 13. Map showing heavy sawfly defoliation of jack pine under and in vicinity of internally growing hardwood.

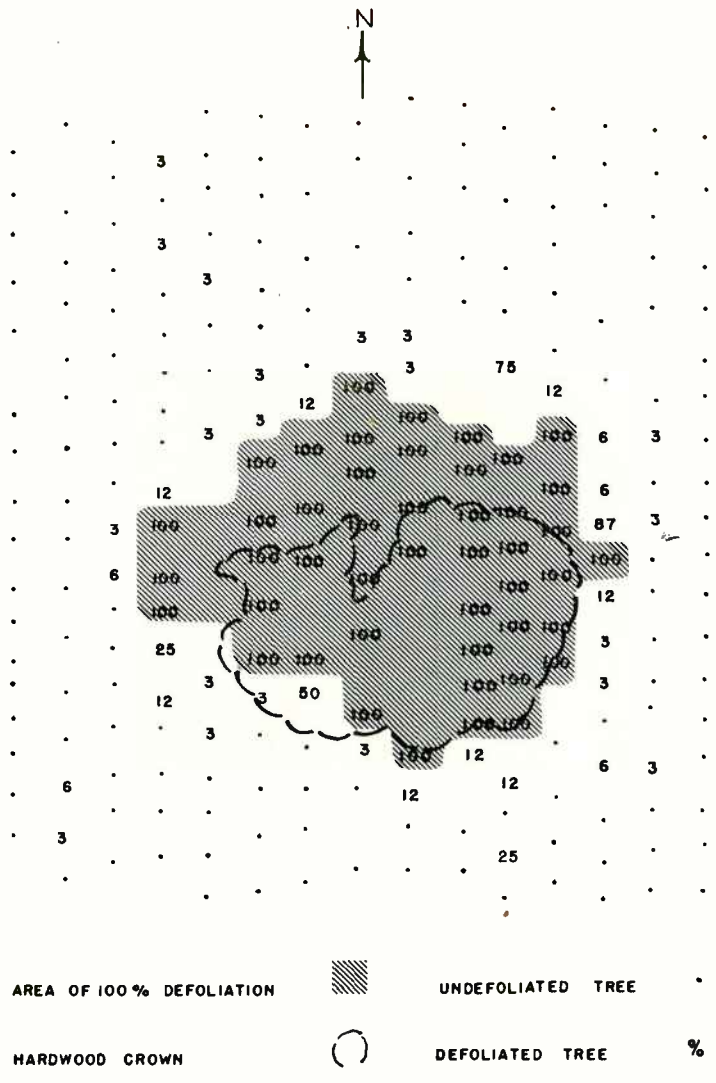


Figure 14. Map showing heavy sawfly defoliation of jack pine under and in vicinity of internally growing hardwood.

Sandblow areas

During the prespray survey of the red and jack pine plantations, trees growing in the sandblow areas were frequently observed to be heavily infested with sawfly larvae while pines growing in sod covered portions of the same plantation were free of larvae. Frequently, pines growing in small sandblows (often less than 1/50th acre in size) were completely defoliated while pines growing in adjacent sod were uninfested. Initial sawfly attack of a one-year-old red pine plantation was observed in which pines growing in a small roadside sandblow approximately 10 square feet in size were attacked while the remainder of the 80 acres of sod-covered plantation was uninfested. Figures 15, 16 and 17 illustrate sandblown sites under heavy attack in the Lower Michigan National Forest.

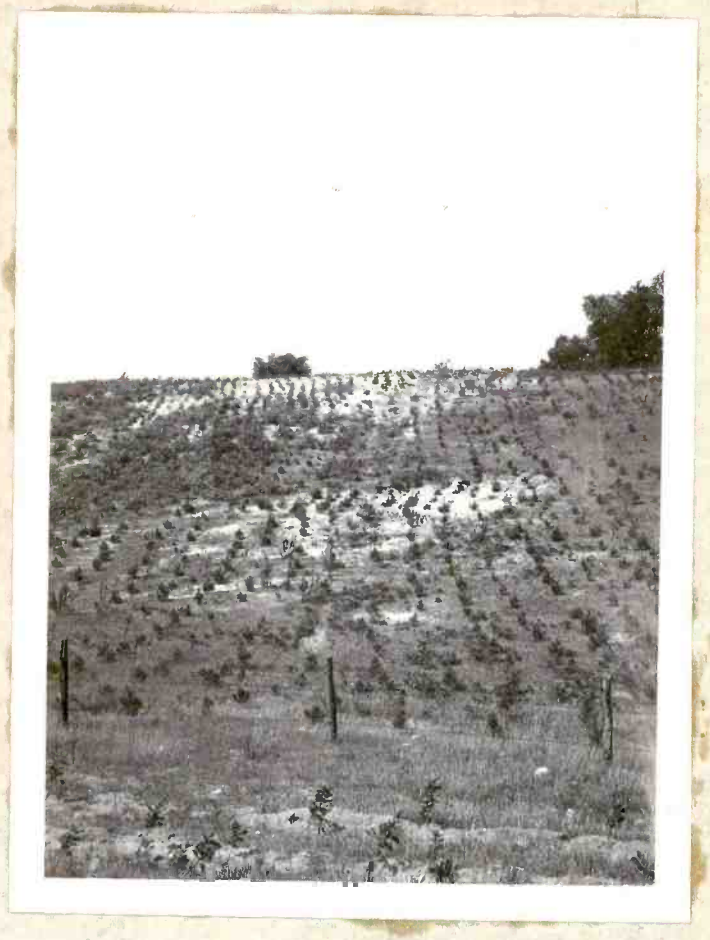


Figure 15. Sandblow areas in the Lower Michigan National Forest under heavy sawfly attack.

Figure 16. Sandblow areas in the Lower Michigan National Forest under heavy sawfly attack.

Figure 17. Sandblow areas in the Lower Michigan National Forest under heavy sawfly attack.

The preference of the female sawflies for sandblow-growing pines over sod-growing pines during oviposition appears contradictory in view of the seeming shade preference exhibited by female sawflies. Examination of sandblow-growing pines indicated that live branches on these trees extend down the main stem and the lowest branches frequently lie in contact with the soil, thus offering densely shaded needles. The live branches on the sod-growing trees also extend down the main stem of the pines but seldom present as densely shaded needles as the sandblow-growing pines. The fact that live branches on edge-growing pines also extend down the main stem of the tree and present more densely shaded needles than trees growing in the central portions of closing pine plantations appears to support this light-oviposition relationship.

Viewed from this aspect, light may still be considered as playing a prominent part in the tree and subsequent egg site selection of the ovipositing female sawflies. What role survival during the cocoon stage plays in the population dynamics of the sawfly in these ecological sites has not been determined. Rodent trapping revealed little this past season although indications were that rodent activity was less in the sandblow areas than in the sodded areas. Cocoons buried this past fall in the ecologically favorable and adjacent areas will be examined next spring for cocoon survival and rodent predation.

PARASITES

Larval collections made throughout the Lower Michigan National Forest (Cadillac and Manistee Ranger Districts) were put into rearing for parasitization determination. Larval collections were also made in areas where the parasite Microplectron fuscipennis was liberated in 1946.

Egg parasitism was rare on the Lower Michigan National Forest. A few egg collections were made, however, on three plantations on the Cadillac Ranger District. Parasitism of these collections was as follows:

Site of Collection	Percent of Parasitization	Basis of No. Eggs Collected
1. Natural jack pine reproduction under hardwood edge, average height 6"	93 33 7 2	150 33 103 137
2. Natural jack pine reproduction under hardwood, average height 12". Two years old.	65	119
3. Open growing jack pine in plantation sandblow, average height 12". One year old.	50 35 9 4 2	118 54 45 256 44